New optical telescope projects at Devasthal Observatory

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ABSTRACT

Devasthal, located in the Kumaun region of Himalayas is emerging as one of the best optical astronomy site in the continent. The minimum recorded ground level atmospheric seeing at the site is $0\rlap{.}''6$ with median value at $1\rlap{.}''1$. Currently, a 1.3-m fast (f/4) wide field-of-view ($66'$) optical telescope is operating at the site. In near future, a 4-m liquid mirror telescope in collaboration with Belgium and Canada, and a 3.6-m optical telescope in collaboration with Belgium are expected to be installed in 2013. The telescopes will be operated by Aryabhatta Research Institute of Observational Sciences. The first instruments on the 3.6-m telescope will be in-house designed and assembled faint object spectrograph and camera. The second generation instruments will be including a large field-of-view optical imager, high resolution optical spectrograph, integral field unit and an optical near-infrared spectrograph. The 1.3-m telescope is primarily used for wide field photometry imaging while the liquid mirror telescope will see a time bound operation to image half a degree wide strip in the galactic plane. There will be an aluminizing plant at the site to coat mirrors of sizes up to 3.7 m. The Devasthal Observatory and its geographical importance in between major astronomical observatories makes it important for time critical observations requiring continuous monitoring of variable and transient objects from ground based observatories. The site characteristics, its expansions plans and first results from the existing telescope are presented.

Keywords: Astronomical site, Optical telescope and instrumentation, Devasthal Observatory, Atmospheric seeing, Sky darkness, Liquid mirror telescope

1. INTRODUCTION

Aryabhatta Research Institute of Observational Sciences (acronym ARIES)[1,2] an autonomous research institute under the Department of Science and Technology, Government of India, has taken initiative to establish moderate size (up to 4-m class) optical telescopes at Devasthal in Nainital, India. The Devasthal* is located in the foothills of central Himalayas. The technological advancements and the availability of sensitive detectors have made moderate size optical telescopes extremely valuable even today due to the increased level of performance, minimal maintenance and specific scientific goals. Furthermore, such telescopes at a good astronomical site have several advantages over very large (10-m class) and giant (30-m class) ones, e.g. in efficiency, availability, survey work, serendipitous discovery and time-critical observations[3,4]. A wide field 1.3-m optical telescope has successfully been installed at Devasthal in the year 2010 and another 3.6-m optical telescope having active optics technology is being built. The Devasthal will also host a 4-m optical telescope having liquid mirror technology, being constructed in collaboration with Belgium and Canada. As these telescopes are being installed at a good observing site and also are being located at a crucial geographical longitude on the globe, see Figure 1, the Devasthal will have an added advantage for a number of time-critical observations of cosmic events. The Devasthal Observatory is expected to significantly increase the access of moderate size optical telescopes to the Indian astronomical community. The need for an easy access to a well instrumented moderate sized optical telescopes is further underscored by the expected many-fold jump in the required optical observing time by Indian Astronomers in future on account of the upcoming first Indian Multi-wavelength Astronomical Satellite (ASTROSAT)† and already operational Giant Meterwave Radio Telescope (GMRT)‡ at Pune, India.

The next section describes the Devasthal as an astronomical site while the subsequent sections provide scientific objectives, technical descriptions and the preliminary results on the 1.3-m, 3.6-m and 4-m optical telescope projects.

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*Meaning abode of God, Longitude : 79°41′04″E, Latitude : 29°21′40″N, Altitude : 2450 m

†http://www.iucaa.ernet.in/astrosat/

‡http://gmrt.ncra.tifr.res.in/

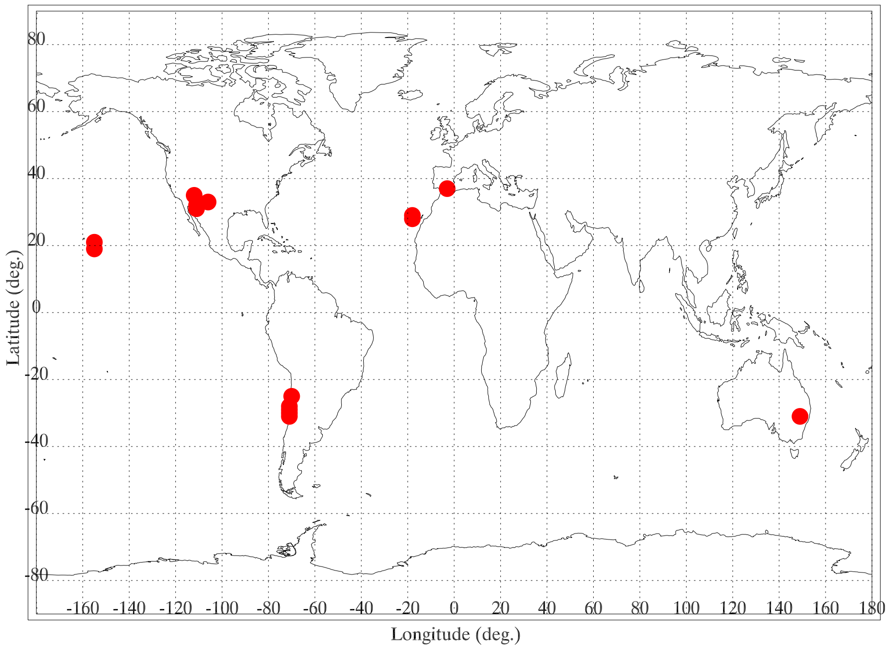

Figure 1. Geographical location of the existing 4-m class optical telescopes located at Mauna Kea (-155°), Kitt Peak (-111°), La Silla (-71°), La Palma (-18°), Calar Alto (-3°) and Siding Spring($+149^{\circ}$) are marked with red circles. The Devasthal ($+79'$) lies at the middle of 12 hours gap in geographical longitudes of Calar Alto in the West and Siding Spring in the East.

2. DEVASTHAL SITE

An extensive site survey conducted in the Kumaun region of the central Himalayas identified Devasthal as a potential site for astronomical observations at optical and near infrared wavebands. It is well connected by road with the Manora Peak[§] located in the vicinity of Nainital[5,6]. The Devasthal and Manora Peak have a longitudinal separation of about 18 km and both the sites are located in the Nainital District of Uttarakhand state in India, and they are operated by ARIES. The geographical location of these astronomical sites are shown in Figure 2.

The site survey work in the Kumaun region was initiated in 1980 and the meteorological observations at a number of places were carried out during 1982-91[7]. The Devasthal peak was located far from any urban development and there was no mountain having higher peak within an aerial distance of 1 km. The Devasthal also offered about 210 useful spectroscopic nights, out of which a good fractions (80%) of the nights are of photometric quality. A detailed characterization campaign of Devasthal was performed during 1998-1999[8]. The air temperature at Devasthal varies between -5 to $+22^{\circ}$ C over the year while the intranight temperature variation is less than 2° C. The relative humidity is below 60% during spectroscopic nights, while it can go to very high values during rainy months of July, August and September. The wind speed at Devasthal is below 5 $\mathrm{m\,s^{-1}}$ for about 85% of the time.

The atmospheric extinction coefficients measured during 1998-91[9] with a solid state stellar photometer mounted on a 52-cm reflector resulted in a mean values of 0.49 ± 0.09, 0.32 ± 0.06, 0.21 ± 0.05, 0.13 ± 0.04, and 0.08 ± 0.04 mag airmass^{-1} in the Johnson $UBVR$ and I band respectively. The minimum recorded value of extinction coefficients are 0.38, 0.22, 0.12 and 0.06 mag airmass^{-1} respectively in UBV and R bands. The atmospheric extinction at Devasthal measured recently in December 2010, using CCD camera mounted with a 1.3-m optical telescope, gives a values of 0.24, 0.14 and 0.08 mag airmass^{-1} respectively in Johnson BV and Cousins R band; while the sky brightness is measured to be 21.2 mag airmass^{-2} in V band[10].

[§]Longitude : $79^{\circ}27'26''$E, Latitude : $29^{\circ}21'39''$N, Altitude : 1927 m

Figure 2. Geographical location of the astronomical site - Devasthal in the Indian sub-continent (left). The location is marked with a red dot encircled in white color. Contour map of the Devasthal site (right). The area is about 4 km on a side and the Devasthal Peak lies in the center. Courtesy Google Map.

The seeing measurements carried out on 80 nights during 1998-1999 with a Differential Image Motion Monitor (DIMM) using a 38-cm telescope with the mirror about 2 m above the ground, yielded a median seeing estimate of about $1.''1$; the 10 percentile values lie between $0.''7$ to $0.''8$ (mean = $0.''75$) while for 35% of the time the seeing was better than $1''$[8, 11]. The inference of a true median seeing for a site depends on many other factors, for example, statistics, instrument used and data reduction procedures. In the present case, the seeing measurements are made using DIMM with a 10 ms exposure time, using a hole separation of 24 cm and a pixel separation of 60. It is observed that a finite, say 10 ms exposure is likely to under estimate the seeing by 10 percent. This shall degrade our median seeing estimate to about $1.''2$ Full Width at Half Maximum (FWHM). Furthermore, the above median seeing ($1.''1$) estimate are performed at 2 m above ground level and it is observed that a seeing of $0.''86$ is contributed by the 6 to 12 m slab of the Devasthal Earth's atmosphere above the ground[11, 12]. Consequently, if a telescope is placed at around 8 meters above ground, a median seeing of sub-arcsec (about $0.''6$) could be expected at Devasthal. In addition, the free air seeing gets further degraded by the local air turbulence due to dome design. This effect may be from a few percent to tens of percent. It, is therefore suggested that for a height of 8 m above ground the best seeing (10 percentile) value for Devasthal can be taken as $0.''7$ FWHM.

The infrastructure development has been carried out extensively at Devasthal site. The nearest state road is at 3.5 km away from the Devasthal Peak. The institute has built a 6 m wide metalled road up to the peak. There is a high speed 2.4 GHz microwave link of 18 Mbps bandwidth between Manora Peak and Devasthal. The requirements of water is met by deep borewell and through rainwater recharging pits.

3. 1.3M DFOT - DEVASTHAL FAST OPTICAL TELESCOPE

In October 2010, a new modern 1.3-m DFOT has been installed successfully at Devasthal[10]. A picture of the telescope and its enclosure is given in Figure 3. In order to avoid degradation of seeing due to local environments, the telescope is mounted 3 m above the ground and the enclosure has a roll-off roof design. The telescope design of the 2-mirror Ritchey-Chrétien optics along with a single element corrector is optimized to deliver a fast beam (f/4, plate scale of $40''\,\mathrm{mm}^{-1}$) and a naturally flat-field of $66'$ diameter at the axial Cassegrain focus[13]. It is therefore suitable for wide-area survey of a large number of point as well as extended sources. The telescope optics can deliver images with 80% encircled-energy (E80) diameter of $0.''6$ at visible wavebands (or equivalently a Gaussian Point Spread Function (PSF) of $0.''4$ FWHM). Without autoguider the tracking accuracy of the telescope is better than $0.''5$ in an exposure of 300 s up to a zenith distance of 40°. The pointing accuracy of

Figure 3. The 1.3-m Devasthal Fast Optical Telescope at Devasthal (left) and its roll-off roof enclosure (right).

the telescope is better than $10''$ Root Mean Squared (RMS) for any point in the sky. Further technical details on the as-designed specifications of the telescope system are given elsewhere[14] . The main scientific objective is to monitor optical and near infrared (350-2500 nm) flux variability in the astronomical sources such as transient events (Gamma-ray bursts, supernovae), episodic events (active galactic nuclei, X-ray binaries and cataclysmic variables), stellar variables (pulsating, eclipsing and irregular), transiting extrasolar planets - and to carry out photometric and imaging surveys of extended astronomical sources, e.g. HII regions, star clusters, and galaxies. Further details on the scientific objectives can be found elsewhere.[2]

During commissioning phase, the telescope was equipped with a 13.5 μm pixel, 2k$\times$2k Andor iKon Camera[¶] which covers a square area of about $18'$ sky on a side. A set of Johnson-Cousins B, V, R and H_α filters, circular in size and providing unvignetted field of $18'$ diameter on CCD were available. For near-zenith observations, in about $2''$ FWHM PSF, we could reach a signal-to-noise ratio of 5 for 20 mag in B and 21 mag in V and R in five summed images of 10s each. The atmospheric extinctions in B, V, and R are estimated as 0.16 ± 0.01, 0.11 ± 0.01 and 0.05 ± 0.02 mag airmass^{-1} respectively on 30th November 2010.

In order to know the detection limits of low-amplitude flux variations in brighter (~ 10 mag) celestial sources set by scintillation in the Earth's atmosphere, we also carried out photometric observations of a known transiting extrasolar planet WASP-12 ($\alpha_{\rm J2000} = 06^{\rm h}30^{\rm m}32^{\rm s}$, $\delta_{\rm J2000} = 29°40'40''$, $V = 11.7$ mag). We used 16μm pixel, 512$\times$512 Andor iXon Camera[‖] which covers a square area of $7'$ on a side. On 5$^{\rm th}$ February 2011, we recorded a set of 3300 CCD frames of 5 s each in Cousins R-band during a continuous observations for 4.5 hours. The observations were made without auto guider. The data reduction procedures are described elsewhere[15] and the differential light curve was generated using ensemble photometry by employing four comparison stars. The differential light curve had a typical photometric accuracy of 3 mmag. To improve the signal-to-noise ratio, we co-added 20 frames of 5 s each and this co-added differential light curve of the WASP-12 transiting system along with the model fit indicates a photometric precision of 1 mmag for a 11.7 mag star (see Figure 4). As a comparison, a similar observations using 104-cm Sampurnanand Telescope at Manora Peak, we get an accuracy of about 3 to 4 mmag. Hence the 1.3-m DFOT at Devasthal would be suitable for the scintillation limited science programs requiring a detection of few mmag on a time scale of hrs (e.g. exoplanet search and AGN variability).

A detailed report on commissioning of the 1.3-m DFOT can be found elsewhere[16] .

[¶]http://www.andor.com (Model DZ436)

[‖]EMCCD Model DU897

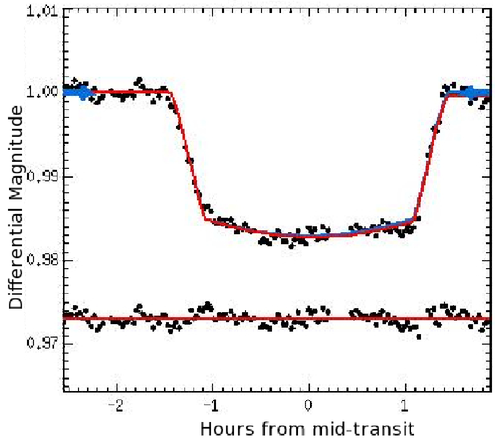

Figure 4. The R-band differential light curve of the transiting extrasolar planet WASP12 ($V \sim 11.7$ mag star) observed on 5$^{\rm th}$ February 2011 with the 1.3-m DFOT at Devasthal, Nainital. The model is overplotted and a typical error in each data point is of the order of 1 mmag.

4. THE 3.6M DOT - DEVASTHAL OPTICAL TELESCOPE

The 3.6m DOT facility consist of a modern 3.6 meter optical telescope, a suite of instruments, an observatory with an aluminising plant, a control room and a data center. The telescope will have a number of instruments providing high resolution spectral and imaging capabilities at visible and near-infrared bands. In addition to optical studies of a wide variety of astronomical topics, it will be used for follow-up studies of sources identified in the radio region by GMRT and UV/X-ray by ASTROSAT. The contract to design, manufacture, integration, testing, supply and installation at Devasthal of the 3.6m DOT is awarded to the Advanced Mechanical and Optical System (AMOS) Belgium** in March 2007 and as on May 2012, the telescope is fully assembled with real mirrors at the AMOS workshop and the tests to verify the telescope performance are being performed.

4.1 Telescope

A computer rendering of the complete as-built telescope is shown in Figure 5. The telescope is a two-mirror RC system with f/9 configuration and an alt-azimuth mount††. The primary mirror is made from a thin meniscus ZERODUR‡‡ glass having a focal ratio of f/2, a clear aperture of 3.6 m diameter and a thickness of 165 mm. The secondary mirror is made from a plano-plano Astrositall glass having a diameter of 0.98 m. Both, the primary and secondary mirrors of the telescope are polished at the Lytkarina Optical Glass Factory (LZOS)*, Russia and the polishing accuracy (RMS wavefront error at 600 nm) of 35 nm for primary and 30 nm for secondary has been achieved[20]. In order to exploit the best seeing ($0\overset{''}{.}7$) at Devasthal, the optics of the telescope is designed to deliver E80 in less than $0\overset{''}{.}45$ diameter (or equivalently a WFE RMS $<$ 210 nm) in a $10'$ arcmin Field of View (FoV) over 350 nm to 1500 nm wavelength range without corrector. The RMS WFE of as-built telescope at worst altitudes is computed as 137 nm for side port and 184 nm for axial port. A preliminary speckle imaging tests performed at the AMOS workshop suggest that the as-built optics can deliver images with E80 better than $0\overset{''}{.}3$ diameter[21].

The azimuth, altitude and other bearings of the telescope uses latest technology available in the market[22]. The tracking performance of the telescope is better than $0\overset{''}{.}1$ RMS for one minute in open loop for wind inside the dome of less than 3 m s^{-1} and in close loop it is $0\overset{''}{.}11$ for less than one hour. In open loop and for wind inside

**http://www.amos.be

††More details on the as-designed technical specifications as well as a general description of the telescope can be found elsewhere[14, 17–19]

‡‡http://www.schott.com

*http://www.lzos.ru

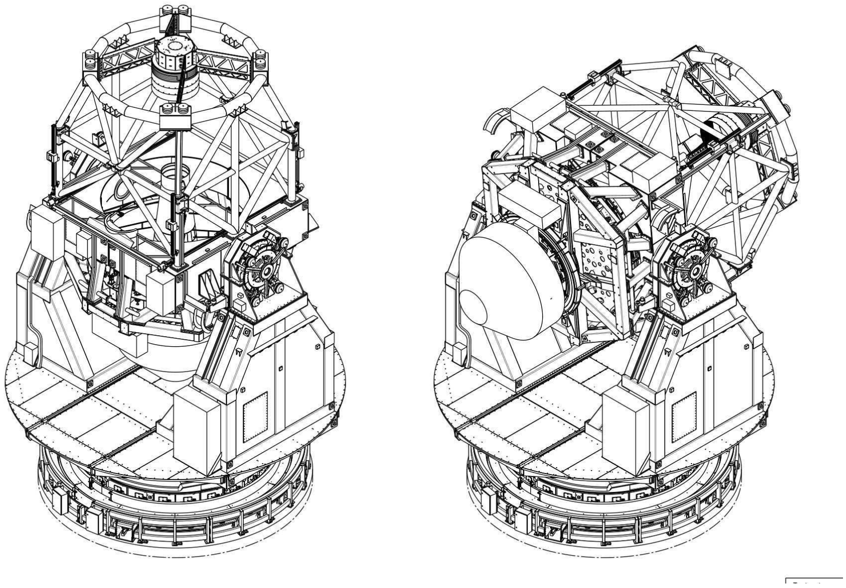

Figure 5. The isometric view of the final design of the 3.6-m DOT - zenith position (left), horizon position at 85 deg zenith distance (right). The telescope is 13.3 m high and it weighs 149.3 ton.

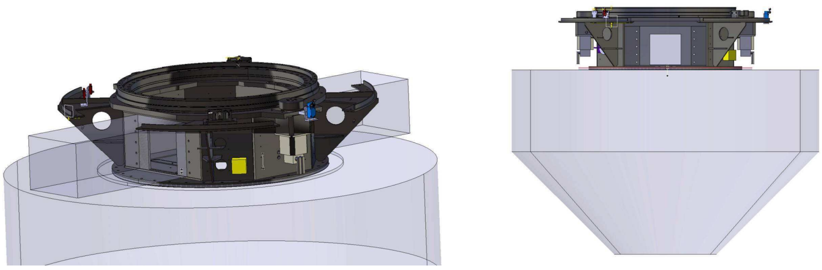

Figure 6. The instrument mounting interface of 3.6-m DOT is shown. The computer rendering of instrument envelope for two side ports and one axial port is also shown.

the dome of 5 $\mathrm{m\,s^{-1}}$ the tracking accuracy is $\sim 0.''5$ peak in 15 minute. The preliminary test results performed at AMOS workshop obtains a value of $0.''2$ RMS in open loop for 10 minutes. The pointing accuracy is better than $2''$ RMS for any point in the sky with elevation greater than 10° and wind inside the dome of less than 5 m/s. For an offset of $10'$ the pointing accuracy is $0.''1$ RMS with wind inside the dome of less than 3 $\mathrm{m\,s^{-1}}$. The telescope can slew in azimuth with $2^\circ\,\mathrm{s^{-1}}$ and in altitude with $1^\circ\,\mathrm{s^{-1}}$.

The telescope has an auto-guiding and wavefront sensor unit which are used to calibrate the telescope's performance with the help of a bright star picked up from the annular ($31'$-$35'$ diameter) region of field of view. The telescope is also equipped with the active optics system (AOS)[23] which is a low frequency system that detects and corrects deformations, aberrations or any other phenomenon that degrade the image quality of the telescope. The AOS consists of a wave front sensor, 69 pneumatic active M1 support systems, M2 hexapod and the telescope control system[24] that acts as interface between each element.

The telescope is provided with instruments mounting cube with one axial port with $30'$ FoV and two side ports with $10'$ FoV, see Figure 6. The axial port can also be fitted with a detachable $30'$ wide field three-lens corrector unit. The main axial port is designed for instruments weighing 2000 kg, while side ports are designed for mounting instruments with 500 kg each. The Cassegrain end can also take imbalance for 2000 Nm on altitude axis and 400 Nm on rotator axis. The axial port instrument envelope is a cylindrical cum conical space of 1.8 m height below the axial instrument flange. A cylindrical diameter of 3 m from flange to 0.8 m and a decreasing conical diameter from 3 m to 1 m corresponding to the distance below the flange from 0.8 m to 1.8 m. The side port instrument envelope is a cuboid of sides 380 mm, 500 mm and 1000 mm.

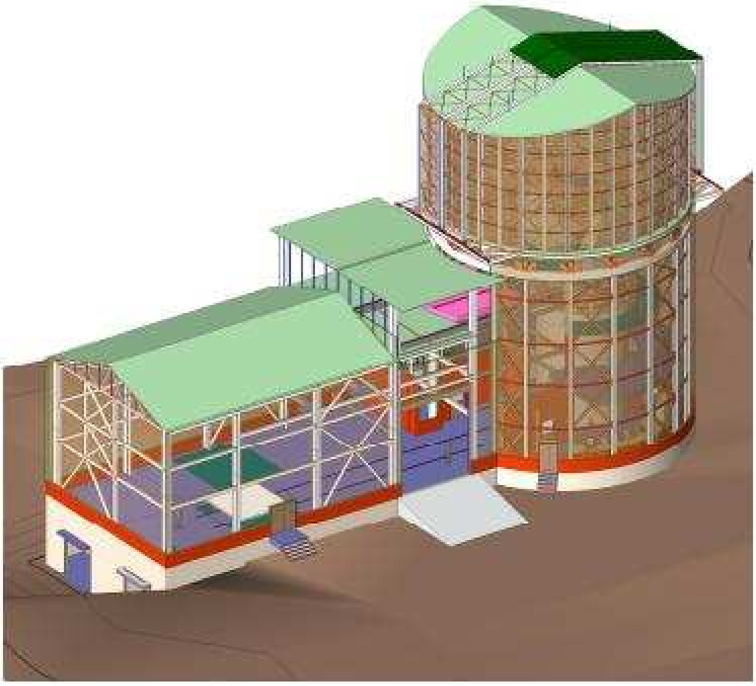

Figure 7. The concept design of the 3.6-m DOT building.

4.2 Telescope enclosure and extension building

The contract to design, engineering, procurement assistance, inspection, and testing of enclosure and auxiliary building for the telescope is awarded to Precision Precast Solutions Private (PPS) limited, Pune[†]. The contract for 'manufacture, supply, erection and commissioning of telescope enclosure structure and equipments is awarded to M/s Pedvak Cranes Privated Ltd., Hyderabad. The final design for the telescope house is shown in Figure 7. The telescope building structure is divided into three parts - the rotating dome (fully insulated steel framed structure), the dome building and the extension building. The design of the civil work up to plinth level of the telescope site is done by PPS, while the civil work up to plinth level was completed by local builders.

Considering space limitation at the site, a 16.5 m diameter dome building and an off-centered telescope pier has been envisaged, see Figure 8. The gyration radius of the telescope is 5.749 m. The foundation and structure of the telescope pier (cylindrical, 8.2 m high above plinth level and 7 m width) is fully isolated from the dome structure to avoid transfer of vibrations. The level of primary mirror will be at about 14.2 m above the plinth level of the ground. The as-designed analysis indicates that the natural frequency of the bare pier is 25.44 Hz for first lateral mode in Z-direction, while for both the pier and the telescope is 14.259 Hz. The first Eigen frequency of the telescope is 7.4 Hz as estimated from finite element analysis. To avoid degradation of seeing due to local heating, two separate ventilation ducts - one from telescope floor and another from telescope technical room along with the exhaust fans have been provided (see Figure 8). Further details on the enclosure design of the telescope can be found elsewhere[25] .

An observatory control and data archive system for the telescope is being developed in-house at ARIES. The synchronization of telescope motions with the dome motions is a bit tricky in case of 3.6-m DOT as the telescope center and the dome center are separated by about 1.85 m. The study found that there would be two regions of avoidance near zenith (blind spot), one for the telescope and another for the dome.

4.3 Aluminising plant

The first aluminization of the primary mirror shall be done at Devasthal before final performance test of the telescope. A contract for design, manufacture and commissioning of an aluminium coating plant for mirrors up

[†]http://ppspl.com

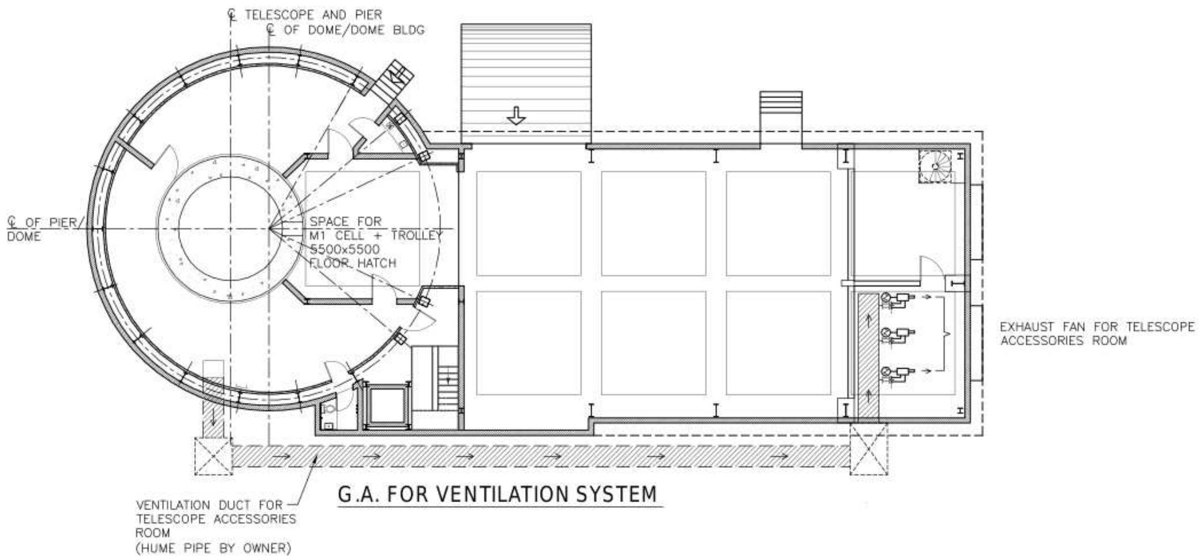

Figure 8. The floor plan of the 3.6-m DOT dome and the extension building. The extension building will house the aluminising plant (see §4.3.)

to 3.7m diameter has been awarded to Hind High Vacuum (HHV) Company Private Limited, Bangalore[‡]. The aluminium sputtering plant has been designed, manufactured, assembled and tested at the HHV workshop. The tests performed at the workshop indicates that the aluminium deposition of 1000Å can be done with uniformity of 25Å. The reflectivity measurement done on sample mirrors have resulted in a value of $92 \pm 2\%$ for the wavelength range 350-850 nm. The coating plant has been shipped to the Devasthal site and it will be installed in the extension building of the telescope house. Further details on the coating plant can be found elsewhere[26].

4.4 Instrumentation

The first generations focal plane instruments are a faint object spectrograph and camera, a high resolution fiber-fed optical spectrograph, an optical–near infrared spectrograph and imager, and a CCD optical imager (see Table 1).

The Faint Object Spectrograph and Camera (FOSC) is a focal reducer instrument. The instrument shall work in imaging and spectroscopic mode. The instrument will have imaging capabilities with one pixel resolution of less than $0\farcs2$ in the FoV of $\sim 14' \times 14'$ of the telescope, and low-medium spectroscopy with spectral resolution (250-4000) covering the wavelength range from 350 nm to 900 nm. A computer simulation indicate that we can image a 25 mag star in V band with an hour of exposure time. The optical and mechanical design of the instrument has been completed in-house at ARIES. Further technical details can be found elsewhere[27].

An optical imager with a 15 micron pixel, 4k×4k back-illuminated CCD detector, liquid nitrogen cooling, full frame window mode operation, and the associated control electronics has also been proposed as a first light instrument. A contract for assembly and integration of the CCD camera has been awarded to Semiconductor Technology Associates, USA[§]. The mechanical interface for the camera is being designed and manufactured in-house at ARIES. The mechanical interface for the camera was completed recently, see Figure 9. This imager will primarily be used to verify the performance of telescope during the commissioning phase. The imager will cover a square area of $6\farcm5 \times 6\farcm5$ on the sky. This instrument will have broadband Johnson-Cousins $UBVRI$ and $ugriz$ SDSS filters, as well as a few narrow-band filters. Once the other proposed instruments are ready for commissioning, the optical imager will be optimized for wide-field imaging at either 1.3-m DFOT or 3.6-m DOT.

In order to complement the photometric and imaging capabilities with spectroscopy, a high resolution spectrograph instrument is envisaged. The main science goals of the proposed spectrograph are asteroseismology,

‡http://www.hhv.in
§http://www.sta-inc.net/

Figure 9. The mechanical design interface for the optical imager.

Table 1. Technical specifications of the proposed Instruments for 3.6m DOT

Parameters	value
Faint object spectrograph and camera:	
Spectral coverage	350-900 nm
Field-of-view	$14' \times 14'$(imaging); $10' \times 10'$(spectroscopy)
Image quality	80% energy in $0\farcs4$ diameter
Resolving power	250-2000 @$1''$ slit-width with single grisms
	4000 @$1''$ slit-width with VPH Gratings
High-resolution optical spectrograph :	
Spectral coverage	380-900 mm
Resolving power	30k and 60k (fixed)
Radial velocity stability	20 $\mathrm{m\,s^{-1}}$ or better
Optical and near-infrared spectrograph and imager:	
Spectral coverage	500 - 2500 nm
Resolving power	3000-4000
Field of view	$7'$
Optical imager:	
Spectral coverage	300 - 900 nm
Field of view	$6\farcm5 \times 6\farcm5$
Spatial resolution	$0\farcs1$ pix^{-1}

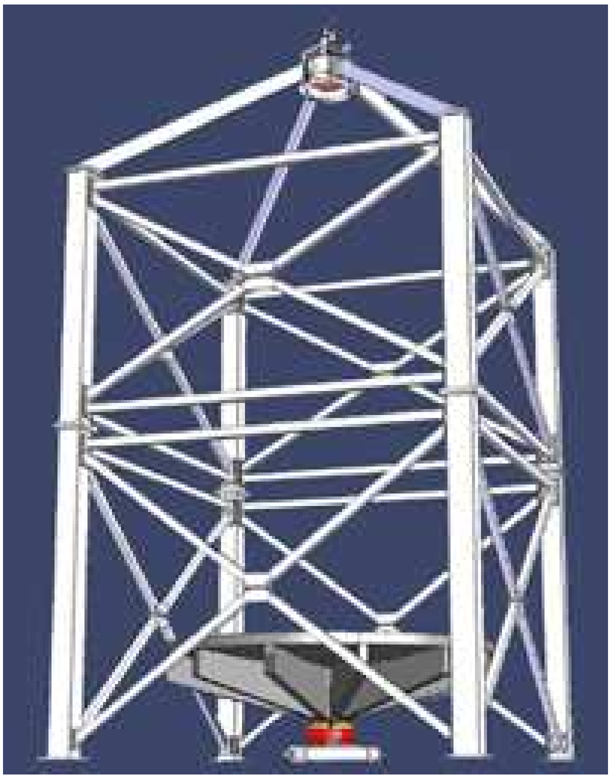

Figure 10. The as-designed view of the 4-m ILMT.

Doppler imaging of spotted stars, massive single and binary stars and abundances studies. The instrument will be based upon a modern design using white pupil concept where a dual mode collimator forms white light image of the grating to be re-imaged by the camera with desired beam size. The concept will be similar to many contemporary high resolution spectrometers such as HERMES, HARPS, ESPaDoNs etc. The spectrograph will provide high-resolution spectra up to spectral resolution of 60k in single exposure and in the wavelength range 380-900 nm. The radial velocity stability is proposed to be better than 20 $\mathrm{m\,s^{-1}}$. The instrument shall be capable of measuring spectrum with signal-to-noise ratio of 100 per 20 $\mathrm{km\,s^{-1}}$ bin for an integration time of one hour for a star of $V \sim 16$ mag.

A general purpose optical and near-infrared spectrograph and imager is proposed jointly by Tata Institute of Fundamental Research[¶], Mumbai and ARIES for observations in the near-infrared bands between 500 nm to 2500 nm. It will use a 1024×1024 Hawaii HgCdTe detector array manufactured by Rockwell International USA and will have flexible optics and drive electronics that will permit a variety of observing configurations. The primary aim of this instrument would be to obtain broad and narrow band imaging of the fields as large as $6' \times 6'$ and also to use it as a long-slit spectrometer with moderate resolving power ($\lambda/\Delta\lambda \sim 3500$) when attached to the telescope. The proposed instrument when coupled with the 3.6-m telescope is expected to reach the 5σ detection of 22.5 mag in J, 21.5 mag in H and 21.0 mag in K with one hour integration.

5. 4-M ILMT - INTERNATIONAL LIQUID MIRROR TELESCOPE

The 4-m ILMT uses Liquid Mirror Technology and the mercury mirror of the ILMT will have a 4 m diameter with a focal ratio of f/2 (see Figure 10). The ILMT is proposed to be installed at Devasthal as a joint collaboration between India, Belgium and Canada. It will perform as a transit telescope. A CCD detector shall be positioned at the prime focus of the telescope. The mirror being parabolic in shape needs a corrector to get a flat focal surface of about $30'$ diameter. The rotation of the Earth induces the motion of the sky across the detector

[¶]http://www.tifr.res.in

surface. The CCD detector works in a Time delay integration mode, i.e. it tracks the stars by electronically stepping the relevant charges at the same rate as the target moves across the detector, allowing the integration as long as the target remains inside the detector area. At the latitude of Devasthal, a band of half a degree covers 156 square degrees, with 88 square degrees being covered at high galactic latitude (b $>$ 30°) including the direction of the north galactic pole. The nightly integration times are rather short, typically 120 s but it is possible to co-add data from selected nights in order to get sky images of longer integration times.

The expected limiting magnitudes are 24.5 at U, B and V bands, 23.5 at R and I bands and 22.3 at Gunn-z band. The expected database towards the Galactic Bulge direction includes 10 million stars, 30000 variables, 8000 binaries, 8000 LPVs/SRVs, 5000 spotted RSCVn, 1400 RR Lyrae, 250 δ-Scuti, 20 Cepheids, 50 yr^{-1} microlenses and 5 yr^{-1} Cataclysmic variables - providing valuable inputs for the studies of stars, galaxies and cosmology.

Further details on 4-m ILMT can be found elsewhere‖.

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